

7 Total Station Survey System (TSSS) Survey Specifications

Survey specifications describe the methods and procedures needed to attain a desired survey accuracy standard. Specifications in this section are based on Federal Geodetic Control Subcommittee (FGCS) standards and specifications. Except where noted, they have been modified to meet the specific needs and requirements for various types of second-, third- and general order TSSS surveys typically performed by or for the Department. For complete accuracy standards, refer to Chapter 5, “Accuracy Classifications and Standards.”

Caltrans TSSS survey specifications shall be used for all Caltrans-involved transportation improvement projects, including special-funded projects.

Total stations are always improving. As the equipment improves, new specifications will be developed and existing specifications will be changed.

7.1 The TSSS Method

The TSSS is a system that includes an electronic theodolite, electronic distance measuring instrument (EDMI), and an electronic data collecting system. The system also includes tripods, tribrachs, prisms, targets and prism poles.

The TSSS system is used to perform the conventional survey methods of traverse, network, resection, multiple ties, and trigonometric leveling.

All TSSS equipment must be properly maintained and regularly checked for accuracy. See Chapter 3, “Survey Equipment,” for equipment repair, adjustment, and maintenance.

7.2 General TSSS Survey Specifications

7.2-1 Redundancy

When proper procedures are followed, a TSSS survey generally can easily meet the accuracy standards for Caltrans second-order, third-order, and general-order surveys. These procedures include redundancy of observations, thereby reducing the possibility of blunders. Also, a complete set of angles is observed whenever establishing or tying existing critical points such as control points and land net points. Redundant observations such as multiple ties should be observed to improve the information available from least squares adjustments and to strengthen survey networks.

7.2-2 Equipment Checks

Total station vertical index and horizontal collimation should be checked each day.

Systematic errors due to poorly maintained equipment must be eliminated to ensure the collection of valid survey data. Optical plummets, laser plummets, tribrachs, tripods, and leveling bubbles should be checked and adjusted regularly. Barometers and thermometers should be checked regularly for accuracy. Equipment acquisition, repair, adjustment, and maintenance is covered in Chapter 3, "Survey Equipment."

7.2-3 Set Up

Height of instrument and target: Measure and enter the H.I. and H.T. into the data collector at the beginning of each set up. It is advisable to check target and instrument heights at the completion of each set up along with the plummet's position over the point.

Temperature and barometric pressure: Measure and enter the appropriate ppm correction into the total station before work is begun each day for general-order and third-order surveys. For second-order surveys, temperature and pressure readings should be made and ppm correction entered into the total station again at midday. Each 1°C change in temperature will cause a one ppm error, if the ppm setting in the total station is not changed.

Checking: After setting up, measure the distance to the backsight to provide a check. Observations of other known points are encouraged whenever practical. For general-order surveys, it is good practice to observe selected points from two set ups as a check. At the conclusion of each set up, the direction to the backsight should be reobserved. For general-order surveys (construction staking, topographic surveys, etc.), areas surveyed from two different set ups should have common points from the two set ups to provide additional checks.

Mode: All distance observations shall be taken in the most accurate measurement mode on the total station.

7.2-4 Field Notes

Original survey notes for all TSSS observations are maintained by the data collector and the Data Collector program. Metadata should be fully filled in and comments about observations that could affect data reduction should be added to the data collector file with a text entry. Data for all points that will be used as control and any land net property corners shall be collected as foresight observations not radial observations in the data collector.

Handwritten survey notes shall be used to supplement the data collector notes. At a minimum, these should include sketches, detailed descriptions and/or rubbings of monuments as appropriate and other general comments about the survey.

For details regarding field notes, see Chapter 14, “Survey Records.”

7.2-5 Survey Adjustments

All control points used for data gathering and stake out, including photo control, shall be adjusted by the method of least squares. Resected control points are adjusted for horizontal position by least squares before they are used in the field.

See Chapter 5, Section 5.4, “Least Squares Adjustment.”

7.3 Second-Order Surveys

7.3-1 Applications

Corridor Control: TSSS can be used to perform second-order trigonometric leveling surveys for Corridor Control Surveys (California High Precision Geodetic Network Densification – HPGN-D).

Project Control: TSSS can be used for horizontal and vertical Project Control Surveys to densify project control established by GPS.

7.3-2 Horizontal Specifications

Method: Traverse with cross-ties.

Table 7-1 lists the specifications required to achieve second-order horizontal accuracy.

7.3-3 Vertical Specifications

Method: Trigonometric Leveling

Table 7-2 lists the specifications required to achieve second-order vertical accuracy.

Note: For specifications for second-order trigonometric leveling acceptable to the National Geodetic Survey (NGS), see *Interim Specifications for Trigonometric Leveling, Second Order, Class II, National Geodetic Survey* – Caltrans, August 4, 1993. All second-order trigonometric leveling surveys submitted to NGS must conform to these specifications.

Table 7-1 Second-Order (Horizontal) TSSS Survey Specifications

Specifications	Traverse/Network
Check vertical index error	Daily
Check horizontal collimation	Daily
Measure instrument height and target height	Begin and end of each setup
Use plummet to check position of target and instrument over points	Begin and end of each setup
Measure temperature and pressure and enter ppm correction into total station	First setup, midday setup
Measure distance to backsight and foresight at each setup	Required
Observe traverse multiple ties	As Feasible
Close all traverses	Required
Horizontal angle observations, minimum	3D, 3R
Vertical angle observations, minimum	3D, 3R
Angular rejection limit, i.e., residual not to exceed	5"
Maximum value for the standard error of the mean of the horizontal and vertical angles	0.8"
Minimum number of distance measurements	3
Distance rejection limit; residual not to exceed	2mm + 2 ppm
Minimum distance measurement	100 m

Table 7-2 Second-Order (Vertical) TSSS Survey Specifications

Specifications	Trigonometric Leveling
Check vertical index error	4 times per day
Use fixed height tripod	Required
Use fixed height staff for target	Required
Measure temperature and pressure and enter ppm correction into total station	First setup, midday setup
Vertical angle observations	2D, 2R <i>(See Note)</i>
Angular rejection limit, i.e., reject if different from mean of observations is greater than	10"
Measure uncorrected zenith distance	Each pointing
Measure uncorrected slope distance	Each pointing
Difference between two differences in elevation for each setup not to exceed	1.5 mm
Maximum sight length	70 m
Minimum ground clearance of line of sight	1 m
Difference between backsight and foresight lengths not to exceed	10 m

Note: Two sets; each set of observations (2D, 2R) yields an independent difference in elevation between the backsight and foresight.

7.4 Third-Order Surveys

TSSS can be used for both third-order horizontal and vertical positioning.

7.4-1 Applications

- Supplemental Control Surveys for Construction and Engineering Surveys
- Photogrammetric Control
- Land Net Location Control
- Monumentation Control
- Major Structure and Interchange Staking

Supplemental control points are points that will be used as set-up points to gather topographic data, locate land net monuments, perform Construction Staking and set-out other control and R/W monuments.

7.4-2 Specifications

Methods

- Traverse
- Resection: This method locates the unknown position of a set-up point by observing known positions from the unknown set-up point. Data for resected points are collected as foresight observations. Generally, points should be resected by observing three known points of third order or greater accuracy. Two point resections may be acceptable if the angle between the observed points is less than 135 degrees or greater than 225 degrees. All specifications for third-order must be met.
- Multiple Tie (Intersection): This method locates points of unknown position by observing the points from two or more control points. These observations must be collected as foresight observations not as radial observations.

Table 7-3 lists the specifications required to achieve third order accuracy.

Table 7-3 Third-Order TSSS Survey Specifications

Specifications	Traverse/Network Resection Double Tie
Check vertical index error	Daily
Check horizontal collimation	Daily
Measure instrument height and target height	Begin and end of each setup
Use plummet to check position of target and instrument over points	Begin and end of each setup
Measure temperature and pressure and enter ppm correction into total station	First set-up of day
Measure distance to backsight and foresight at each setup	Required
Observe traverse multiple ties to improve least squares adjustment	As Feasible
Close all traverses	Required
Horizontal angle observations, minimum	3D, 3R
Vertical angle observations, minimum	3D, 3R
Angular rejection limit, residual not to exceed	5"
Maximum value for the standard error of the mean	1.2"
Minimum distance measurement to meet horizontal accuracy standard	50 m
Minimum number of distance measurements	3
Distance rejection limit: residual not to exceed	2mm + 2 ppm
Maximum distance measurement to meet vertical accuracy standard	100 m

7.5 General-Order Surveys

7.5-1 Applications

- Engineering Survey collected topo data
- Construction Survey, staked points
- GIS Surveys
- Environmental Surveys
- Right of Way Surveys

See Chapter 10, “Right of Way Surveys,” Chapter 11, “Engineering Surveys,” and/or Chapter 12, “Construction Surveys” for tolerances and accuracy standards for specific types of surveys.

7.5-2 Specifications

The radial survey method is used for all general-order surveys. Data for general-order points are gathered as radial observations in the data collector and are not available for least squares adjustment.

For construction staking, staked positions are rejected, when the difference between the “set” (observed) position and the theoretical design position exceeds the allowable tolerance. See Chapter 12, “Construction Surveys” for tolerances.

Engineering survey data points are checked by various means including reviewing the digital terrain model, reviewing data terrain lines in profile, and redundant measurements to some points from more than one setup.

Table 7-4 lists the specifications required to achieve general-order accuracy.

Table 7-4 General-Order TSSS Survey Specifications

Specifications	Radial
Check vertical index error	Daily
Check horizontal collimation	Daily
Measure instrument height and target height	Yes
Use optical plummet to check position of target and instrument over points	Begin and end of each setup
Measure temperature and pressure and enter ppm correction into total station	First setup of day
Horizontal angle observations	1D
Vertical angle observations	1D
Minimum distance measurement to meet horizontal accuracy standard	20 m
Maximum distance measurement to meet vertical accuracy standard	150 m